§13. Reduction Behavior of Magnetite for Microwave Frequency

Takayama, S., Link, G. (FZK, Germany),
Thumm, M. (FZK, Germany), Matsubara, A.,
Sato, M., Sano, S. (AIST)

In order to investigate the effect of microwave frequency, samples of magnetite powder mixed with carbon powder were processed in different microwave systems. The following paper discusses recent experimental results obtained by millimeter-wave (mm-wave) processing.

“Keywords” Millimeter Waves, Frequency Effects, Reduction Behaver, Microwave Application, Marking Iron

Nagata and coworkers of the Tokyo Institute of Technology have been working on the development of unique ultra high purity iron refinement technology based on an ancient Japanese iron refinement method called "Tatara" method [1]. Their findings during microwave sintering of powder metals led to the idea that rapid refinement of iron should be possible by application of 2.45 GHz microwaves instead of relying on burning of carbon for heat production. Joint experiments at the National Institute on Fusion Science (NIFS) and Forschungszentrum Karlsruhe (FZK) proved that high purity iron (1% carbon concentration) with less than 10% of impurities as compared to iron from modern blast furnaces can be produced in a short time, while reducing the carbon consumption to 2/3.

The weight ratio of mixed magnetite and carbon power was 89 to 11 weight%, which should allow to produce pig iron including 2 weight% of carbon. Such type of powder samples were filled into an alumina crucible surrounded by thermal insulation (see Fig.1). The temperature was measured by two S-type thermocouples, one sticking in the center of the powder sample, another near the crucible wall. This set-up was then placed into the mm-wave applicator of a compact 30 GHz gyrotron system [2]. The mm-wave power generated by a so called gyrotron oscillator can be controlled from 0 - 15 kW. The heating process was controlled along a preset temperature-time program with a heating rate of 70 °C/min using the temperature signal of the thermocouple placed near the sample surface.

The process temperatures measured during mm-wave heating of a powder sample of mixed magnetite and carbon. It can be seen that during the initial step of heating that means during the first 15 minutes, the temperature measured at the sample surface was higher than the temperature measured within the sample volume. However thereafter, the absorption behaviour of the powder is changing dramatically. The heating rate of the sample surface decreases so that after 20 minutes from the beginning, the temperatures measured at both positions became similar. As a result of this Figure 1 shows a picture of the obtained pure pig iron. EDX analysis along the cross section revealed a carbon content of 1 weight%. No oxygen could be detected.

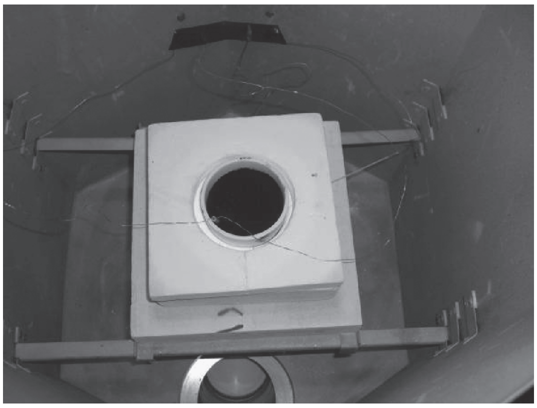

Fig. 1 Experimental setup of the mm-wave process.

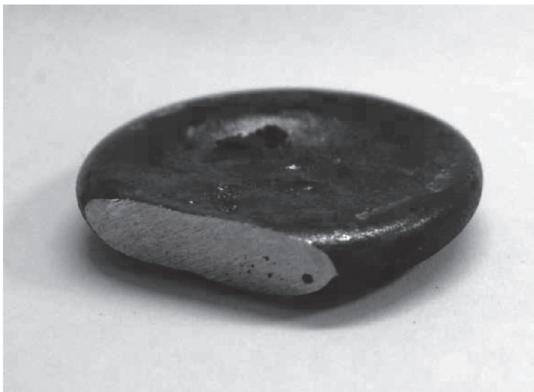

Fig. 2 Pig iron from the 30 GHz mm-waves process.

High quality pig iron could be made from powder samples of mixed magnetite and carbon by 30 GHz mm-waves heating in air. However, in case of heating by 2.45 GHz at similar conditions, mainly FeO was produced. Therefore, we expect that there is a frequency dependence in the reduction reaction.

References

1) K. Nagata, R. Kojima, T. Murakami, M. Susa, H. Fukuyama, “Mechanisms of Pig-iron Making from Magnetic Ore Pellets Containing Coal at Low Temperature”, ISIJ International **41**: 1316-1323, 2001.

2) G. Link et al., “Sintering of advanced ceramics using a 30-GHz, 10-kW, cw industrial gyrotron”; IEEE Transactions on Plasma Science, **27** (2): 547-554, 1999.